



Article

# Transition of Agricultural Mechanization, Agricultural Economy, Government Policy and Environmental Movement Related to Rice Production in the Mekong Delta, Vietnam after 2010

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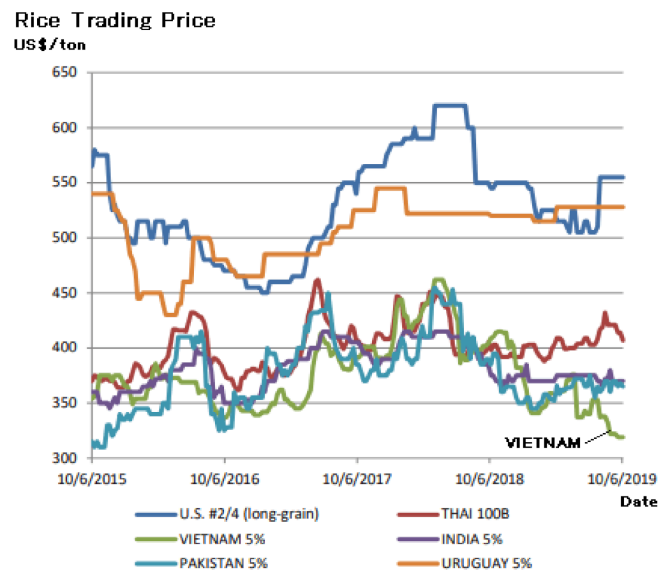
**Abstract:** This study examines sustainable agricultural development in Vietnam by focusing on rice production in the Mekong Delta. Vietnam is the third largest rice-exporting country in the world and more than 90% of rice for export is from the Mekong Delta. We attempt to identify changes in the rice industry, specifically examining farming mechanization, trends in farm operation, and farm household economy. The main structure of our study is based on our direct interviews with 420 farmer households, 81 registered large farm owners, 75 farming service providers, and local government members. We carried out those interviews in 2013 and 2014. We identified several important changes brought by technological advances, economic modernization, government policies, and environmental movements. One important finding was the increasing trend of agricultural land per farmer household, such as from 1.98 to 2.27 ha in 2010 to 2018, and the decreasing trend of labor force, which pushed up agricultural mechanization. Another point was the land law revised in 2013, which allowed farmers to borrow (no private land ownership in Vietnam) farms up to 30ha/household if registered as a “Trang Trai” farm. Farmers accepted the use of tractors and combine harvesters; however, rice seed sowing was not mechanized, so rice transplanters were rarely used for rice planting. Among the processes of rice production, sowing of rice seeds was the least mechanized. In order to achieve more sustainable agricultural practices, we recommend improving the mechanization of the rice seed sowing process for the Mekong Delta farmers with acceptable conditions. Another finding was positive movements among Mekong Delta researchers and farmers to improve their rice quality to be accepted as high-quality rice in the global rice market and to dispel the bad reputation of the past.

**Keywords:** large farm registration system; rice seed row sowing; transplanting machine

## 1. Introduction

Vietnam is the third largest rice exporting country in the world and more than 90% of Vietnamese rice for export is produced in the Mekong Delta [1,2]; Vietnam was even a rice-importing country before 1988 [3]. In recent years, many Asian countries, such as the Philippines and Indonesia, are continuously

rice-importing countries. Vietnam is the top rice supplier to those countries. However, a big part of rice production processes in Vietnam still relies on manual labor work. Moreover, the quality of Vietnamese rice is evaluated as low grade in the international rice trade market (Figure 1) [4,5]. Therefore, we conclude that Vietnam needs to improve its mechanization of rice production in order to improve rice quality as well as productivity.



**Figure 1.** Rice Trading Prices of major rice exporting countries from 2015 to 2019. Vietnamese rice price is always close to the bottom level. Source: created from the data of the United States Department of Agriculture (USDA) [6,7].

Although there are several studies dealing with agricultural mechanization and the situation of rice producing farmer households in Vietnam [8], we were able to find very few studies which examined the relationship between the mechanization movement and the changing environment of farmers. We also could not find studies which utilized interviews with farmers related to mechanization habits or trends in the Mekong Delta. Our paper considers the possibility for mechanizing rice production in Vietnam in order to achieve more sustainable agricultural practices, from land preparation to harvest. In this regard, we have conducted the most research on the level of mechanization in agricultural processes. In order to determine which technological improvements are necessary for producing high quality rice in Vietnam, we investigated the changing demand of agricultural mechanization according to the current mechanization level, farmers' requirements, or farming environment in the Mekong Delta.

In order to understand current situation and find out future possibilities practically, we carried out the following work:

- (1) We collected and analyzed official statistical data, government policies, and other published papers in order to understand the changing social systems or laboring conditions related to rice farmers.
- (2) We conducted interviews to obtain information from stakeholders concerning the current status of mechanization in rice production from 2013 to 2014.
- (3) We tracked and analyzed the data related to rice production in the Mekong Delta after 2014 up to 2019.

## 2. Materials and Methods

### 2.1. Study Target Elements

From 2013 to 2014, for better understanding of the mechanization situation of rice production in the Mekong Delta, we examined the following five (Section 2.1.1 to Section 2.1.5) elements.

#### 2.1.1. Labor Conditions and Methods of Rice Farmers

Operation size of farmer households, farming patterns, mechanization demand, and the functions of businesses providing farm machinery services.

#### 2.1.2. Improvement of Rice Farming Technology

The introduction and adaptation of new technologies for land preparation, seed sowing, fertilizing, chemical spraying, and harvesting. The actions of businesses providing farm machinery services are also important factors affecting agricultural mechanization.

#### 2.1.3. Economic and Workforce Trends in Vietnam

After the economic reform policy “Doi Moi” was announced at the National Assembly of Vietnam in 1986, Vietnam has industrialized and successfully become a major production location for multinational corporations. We subsequently investigated urban migration trends and considered their relationship with the improvement of agricultural productivity and working environments.

#### 2.1.4. Government Policies

The Vietnamese government considers agriculture to be an important national industry. It is notable that the government has provided financial support to farmers to purchase agricultural machinery as well as providing new land use policy for farmers to borrow large farmland.

#### 2.1.5. Environmental Movement

We consider the environmental movement to be an important issue related to agriculture.

In order to achieve these research objectives, we carried out the following activities from 2013 to 2014:

### 2.2. Official Documents Analysis

The General Statistics Office of Vietnam (GSO) issues a statistical report every year and a more detailed report every 5 years. We analyzed relevant data from these reports [9–13]. We also referred to related government regulations, such as Laws, Decisions, Decrees, and other instructions.

### 2.3. Existing Research Review and Analysis

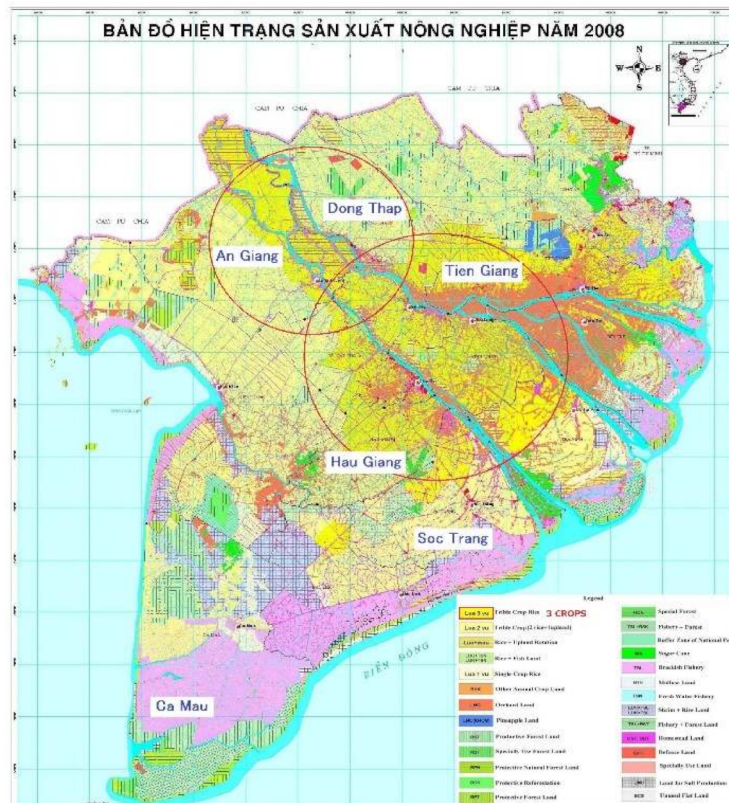
There are many research papers related to Vietnamese agriculture. In particular, research papers by researchers at the Institute of Developing Economies—Japan External Trade Organization (IDE-Jetro) were informative for our study, especially, research for the farmers’ environment, such as the transition of farmers’ communities, lifestyle, agricultural products’ value chain, government policy, etc. [14–21].

### 2.4. Interviews and Discussions with Stakeholders

In order to obtain real data from stakeholders in each category, we carried out five steps of direct data collection from stakeholders: (1) survey design and basic data collection, (2) preliminary interviews with provincial staff members, (3) interviews with 420 farmer households, (4) interviews with 75 business providing farm machinery services, and (5) direct interviews with 81 registered large farm (named “Trang Trai”) owners in 2013.

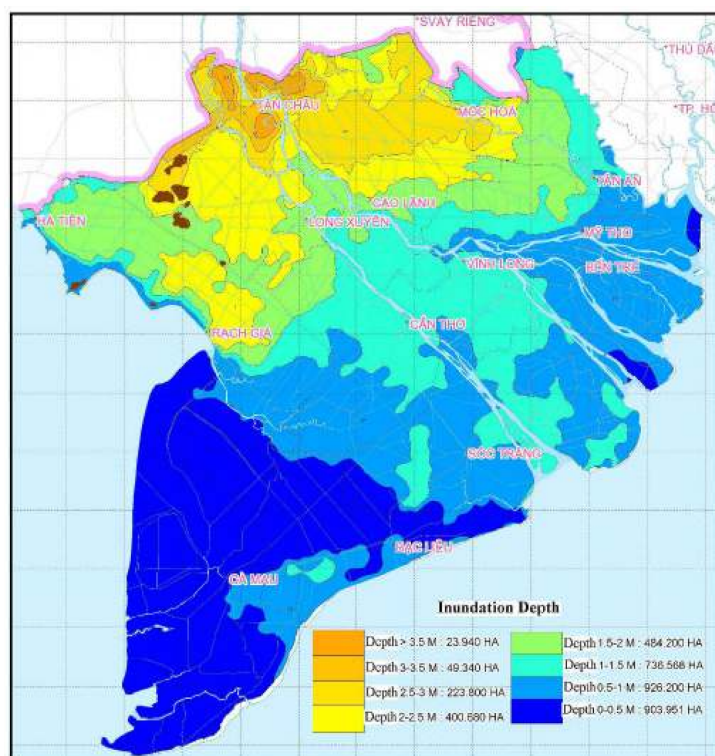
2.4.1. Survey Design and Basic Information of the Target Area

Our research analyzed six representative rice-producing provinces in the Mekong Delta: Tien Giang, Dong Thap, An Giang, Hau Giang, Soc Trang, and Ca Mau provinces (Figure 2). Rice is the main crop cultivated in these provinces; however, rice cropping intensity and the geographical conditions of each province are different as follows:



**Figure 2.** Mekong Delta Agricultural land use map (2008). \* The yellow-colored area is for rice cultivation, and circled areas are mostly triple cropping areas. Land use areas have not changed for most of the Mekong Delta areas since this 2008 map up to 2014, except for some expansion of triple cropping areas from two cropping areas by irrigation system improvements. Source: Southern Institute for Water Resources Planning (SIWRP) [22].

In the northern part of the Mekong Delta, the An Giang and Dong Thap provinces are representative of flood-affected areas with a high intensity of rice production where double or triple rice cropping is common, because the two provinces have a good climate for triple cropping; however, areas where lacking flood prevention embankments are usually double cropping areas (Figure 3). These two provinces also feature large farms compared with farms in other Mekong Delta provinces.



**Figure 3.** Inundation map of the Mekong Delta in 2000 floods. Orange and yellow colored areas (An Giang and Dong Thap province) often suffer heavy floods in the rainy season (inundation in 2000 was serious, and water depth was 2.0–3.5 m). Source: Southern Institute for Water Resources Planning (SIWRP) [22].

The Tien Giang and Hau Giang provinces are representative of the middle region of the Mekong Delta, where flooding is minimal yet high intensity rice cropping takes place (Figure 3).

The Soc Trang and Ca Mau provinces are located in the southern coastal region; therefore, not enough water comes from the Mekong river and partly saline soils are available in those regions, where traditional single season rice or rice–shrimp farming is practiced (Figure 4).



**Figure 4.** Machine transplanting at a wet and muddy field in a Ca Mau province one-crop area (rice and shrimp farming area). The paddy field is surrounded by water where farmers grow shrimp. Rice seedlings are brought by a boat. Source: Photos taken by the author at U Minh, Ca Mau on 11 August 2013.

This study looks at traditional rice cropping, double rice cropping, and triple rice cropping and attempts to identify the important factors influencing the mechanization of rice cropping in each respective region. We designed a questionnaire to inform three separate studies conducted in six provinces.

#### 2.4.2. Preliminary Interviews

Prior to our three separate studies, we carried out focus group discussions and in-depth interviews with provincial staff in all 12 provinces (Dong Thap, An Giang, Kien Giang, Ca Mau, Bac Lieu, Soc Trang, Hau Giang, Vinh Long, Ben Tre, Tien Giang, Long An, Tra Vinh) and one city (Can Tho city) in the Mekong Delta in 2013.

Major points of discussion in the interviews with participants were:

- (1) Factors which either enable or constrain the mechanization of land preparation processes;
- (2) Factors which either enable or constrain the mechanization of seeding and transplanting processes;
- (3) Factors which either enable or constrain the mechanization for rice harvesting;
- (4) Factors which either enable or constrain mechanization for rice drying methods;
- (5) Solutions for mechanization in rice production.

#### 2.4.3. The First Study: Farmer Households

We interviewed a total of 420 households in six provinces in 2013. The location and cropping patterns of surveyed farmer households are shown in Table 1. We asked questions concerning the level of mechanization of rice farming processes, such as land preparation, seed sowing, fertilization, chemical spraying, and harvesting.

**Table 1.** Number of households surveyed by rice cropping pattern and province.

Province \ Pattern	1 Crop	Rice–Shrimp	2 Crops	3 Crops	Total
An Giang	0	0	35	35	70
Dong Thap	0	0	35	35	70
Hau Giang	0	0	35	35	70
Tien Giang	0	0	0	70	70
Soc Trang	0	35	35	0	70
Ca Mau	35	35	0	0	70
Total	35	70	140	175	420

Source: Authors' survey.

Our questionnaire covered the following topics:

Tractors for land preparation are common; however, the majority of farmers asked for land preparation services from service providers. We checked those convenience levels with the following (1)–(3).

- (1) Location of farm machine services provided for land preparation by rice cropping pattern;
- (2) Waiting time for business providing farm machine services for land preparation;
- (3) Rate of questionnaire respondents who wanted to purchase a tractor for land preparation.

In our six surveyed provinces, the rice seed sowing method, such as manual direct seeding “broadcasting”, manual row sowing by drum seeder, and manual transplanting, is different in each area based on climate, water supply, soil, season, or other conditions. We checked sowing methods in each province and cropping pattern separately with the following (4)–(6).

- (4) Current status of rice sowing in the Autumn–Winter season by method;
- (5) Current status of rice sowing in the Winter–Spring season by method;
- (6) Current status of rice sowing in the Summer–Autumn season by method.

Among rice seed sowing methods, the manual direct seeding “broadcasting” method was used by the majority; however, for a trend of better quality and productivity, the mainstream sowing method was changed to manual row sowing by a drum seeder, and partly sifted to use a transplanter. Then, we checked the latest situation with the following (7)–(12).

- (7) How farm machine services for row sowing were procured by rice cropping pattern (2 crops or 3 crops);
- (8) Rate of respondents who wanted to shift from manual direct seeding (broadcasting) to row sowing or machine transplanting;
- (9) Reason for shifting from broadcasting to row sowing;
- (10) Rate of respondents who wanted to shift from row sowing to machine transplanting;
- (11) Reason for shifting from row sowing to machine transplanting;
- (12) Rate of respondents who wanted to purchase a transplanting machine.

Rice cultivation in the Mekong Delta much relies on fertilizer and chemicals because 2 crops or 3 crops cultivation is the majority and a large volume of fertilizers are required to keep the fertility of the soil. Weeding agrochemicals are also required because of the difficulty of mechanical or manual weed control in broadcasted (manual direct seeding) paddy, rice and weed grown in mixed. Then, we checked the related situation with the following (13)–(16).

- (13) Current status of fertilizer application;
- (14) Rate of respondents who wanted to shift from manual fertilizing to mechanized fertilizer application;
- (15) Current status of chemical spraying;
- (16) Rate of respondents who wanted to shift to mechanized spraying application.

Rice harvesting is one of the main works in rice production. After 2009, the rice combine harvester became a very popular machine in the Mekong Delta. Rice is harvested by combine harvester in most of the area; however, most of the farmers use harvesting services performed by service providers. We checked the latest machine service situation with the following (17)–(22).

- (17) Current status of rice harvesting by cropping pattern and season;
- (18) Origin of business providing farm machine services for harvesting by rice cropping patterns;
- (19) Waiting time for companies providing combine harvester services for harvesting;
- (20) Method for obtaining a combine harvester for harvesting;
- (21) Rate of respondents who demanded a shorter waiting time for harvesting;
- (22) Rate of respondents wanted to purchase a combine harvester.

We wanted to know overall mechanization demand or the difficulties in each working process and cropping pattern, and checked those with the following (23)–(25).

- (23) Difficulty of implementing mechanization in rice production according to each stage (difficulty level);
- (24) Priority of mechanization in each stage of rice production;
- (25) Willingness to purchase agricultural machinery by cropping pattern.

#### 2.4.4. Second Study: Business Providing Farm Machinery Services

Farming service by machine is a necessary function of rice production in the Mekong Delta, because each farming scale is rather small and average farmer households cannot own machines by themselves. We interviewed 75 business providers for farm machinery services in six provinces in 2013. Table 2 shows the location of businesses which supply four-wheel drive (4W) tractors, two-wheel

drive (2W) tractors, or combine harvesters. The survey was designed to increase understanding of the operation and economic situation of machinery suppliers.

**Table 2.** Number of farm machinery service providers surveyed by province and service type.

Province Service	Province						Total
	Tractor 4W	Tractor 2W	Combine Harvester (CH)	Tractor 4W and 2W	Tractor 4W and CH	Tractor 2W and CH	
An Giang	8	0	5	0	2	0	15
Dong Thap	5	0	7	3	0	0	15
Hau Giang	3	4	6	1	0	1	15
Soc Trang	4	4	4	0	3	0	15
Ca Mau	7	0	8	0	0	0	15
Total	27	8	30	4	5	1	75

Tractor 4W: four-wheel drive tractor, Tractor 2W: two-wheel drive tractor. Source: Authors' survey.

Our questionnaire covered the following topics:

- (1) Service types and number of farm machinery service provider by province;
- (2) Labor force composition of farm machinery service providers;
- (3) Education level of owners of farm machinery service providers;
- (4) Origin of farm machinery service providers;
- (5) Combination of services and other business of service providers;
- (6) Loans taken out by farm machinery service providers to fund their operations;
- (7) Working day of farm machinery service providers by season and distance;
- (8) Laborers hired by farm machinery service providers and the daily wage earned by these laborers;
- (9) Disadvantages stated by farm machinery service providers;
- (10) Economic analysis of the farm machinery service industry;
- (11) Future business prospects.

#### 2.4.5. Third Study: Large Farm Owners

In order to better understand the demand for mechanization and related trends, we also carried out a survey of 81 registered large farm "Trang Trai" owners in the six provinces in 2013. These data are summarized in Table 3.

**Table 3.** Number of large farms surveyed by province and sector.

Province Sector	Province						Total
	Rice	Livestock	Aqua-Culture	Rice and Aqua-Culture	Rice and Livestock	Livestock and Aqua-Culture	
An Giang	7	0	2	3	1	2	15
Dong Thap	5	4	4	2	0	0	15
Hau Giang	5	3	2	2	3	0	15
Tien Giang	4	5	4	0	3	0	16
Soc Trang	4	3	0	5	3	0	15
Ca Mau	0	5	0	0	0	0	5
Total	25	20	12	12	10	2	81

Source: Authors' survey.



The questionnaire covered the following topics:

Registered large farms “Trang Trai” are registered farm businesses. We checked the actual ability or capacity of “Trang Trai” owners to find out possibilities for farming system development in the Mekong Delta, then we raised the following questionnaires from (1) to (15).

- (1) Gender composition and education level of owners of large farms by agricultural category (sector);
- (2) Composition of laborers at large farm by sector;
- (3) Size of agricultural land of large farms by sector between 2010 and 2014;
- (4) Waiting time for land preparation services by season;
- (5) Origin of tractors used in land preparation;
- (6) Percentages of large farms which requested future land preparation services;
- (7) Current status of rice sowing at large farms;
- (8) Percentage of large farms expected to adopt rice sowing methods;
- (9) Current status of fertilizing and chemical application;
- (10) Percentage of large farms expected to mechanize their fertilizing and chemical application methods;
- (11) Current status of mechanization in harvesting;
- (12) Waiting time and method for accessing (direct or in-direct) combine harvester;
- (13) Origin (location) of combine harvester serviced;
- (14) Percentage of large farms that wanted to purchase a combine harvester;
- (15) Economic analysis of large farms surveyed by sector in 2014.

### 2.5. Movement Follow up after 2013–2014 Survey

After our survey and direct interviews performed in 2013–2014, we carried out follow up data collection and analysis up to 2019 data, to catch the recent movements or trends of rice production in the Mekong Delta.

### 2.6. Basic Method of Data Collection and Analysis

In all the interviews, for the purpose of obtaining clear results, questionnaires were designed with two to six choice questions and did not request numbers, except for some statistical data such as population of tractors, etc. All the collected data were firstly analyzed by Chi-square test or standard deviation to identify significant differences.

## 3. Results and Discussion

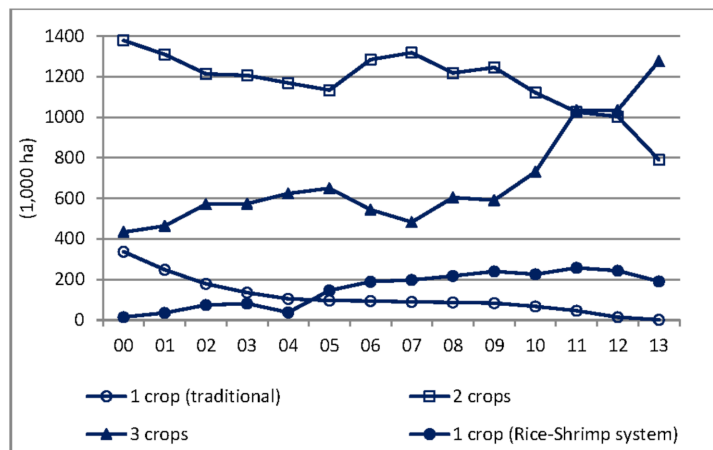
### 3.1. Changes in Farm Size and Rice Production Patterns

There are many changes and shifting factors relevant to rice production farmland in the Mekong Delta.

Average farmland size in the Mekong Delta has increased slightly from 1.98 ha/household in 2010 to 2.13 ha/household in 2014 (Figure 16). Rice production patterns have changed, with many farmers switching from double rice cropping to triple rice cropping (Figure 5) [23], mainly as a result of improvements of the irrigation systems of areas which regularly flood.

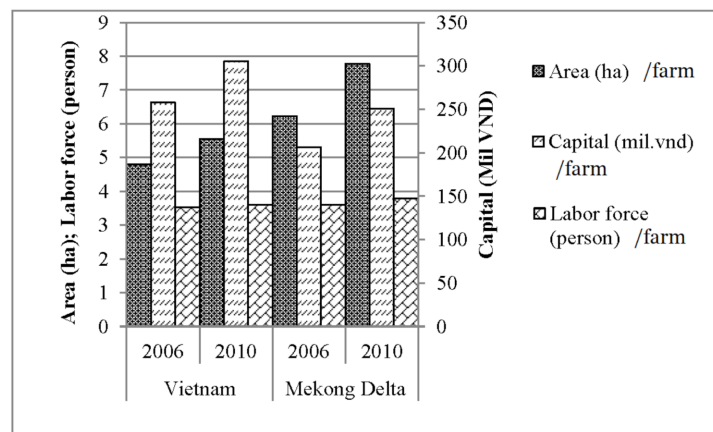
At the same time, the population of farmers has decreased. In particular, the number of small farmer households who own less than 3 ha has decreased from 2001 to 2006 as a result of the majority of the agricultural workforce migrating to large cities [9,24].

However, although the urban–rural income ratio in 2002 was 2.3, it decreased to 2.1 in 2006 and 2008 [18], and dropped again to 1.9 in 2016 [11]. Therefore, a certain section of the working population prefers to be employed at farms in rural areas because of the acceptable working environment, including income [25].



**Figure 5.** Rice cropping patterns change from 2000 to 2013. Source: The Climate Change Affecting Land use in the Mekong Delta: Adaption of Rice-based Cropping Systems (CLUES) project; this figure was not published, related data are available at [26].

In terms of government policy, since Vietnam is a socialist republic, no land ownership is given to a private person officially. In such situation, the land law has been revised regularly, and according to the “Trang Trai” farm registration system, farmers are allowed to borrow (not an ownership) over 3 ha of farmland. This differs from the original land law, which limited farmers to borrow 3 ha of land per household [14]. This process was accelerated by a revision of the law in 2013, which allowed farmers to borrow up to 30 ha for a period of 50 years [15,21]. After the large farm system “Trang Trai” was introduced in 2010, the average size of registered large farms in the Mekong Delta had increased to approximately 8 ha/farm in 2010 (Figure 6).



**Figure 6.** Characteristics of a large farm in all of Vietnam and the Mekong Delta in 2006 and 2010; Source: created from GSO 2013 [9].

Agricultural land policy has also encouraged farmers to support rice production. On 9 April 2016, the government announced its intention to maintain at least 3,763,390 ha of rice paddy fields according to decision No. 134/2016/QH13.

On the other hand, as per Decision No. 586/QD-BNN-TT/2018 passed on 12 February 2018 and amended 4712/QD-BNN-TT on 9 December 2019, the government has instructed farmers to shift from rice production to other profitable products, such as fruits and aquaculture.

In short, farmland for rice cropping per household has increased slightly every year. However, the population of farm labor force has decreased, which accelerates demand for mechanization. However, in the long term, farmers were recommended to partly change their cropping item from rice

to other profitable agricultural products, which will also keep a certain number of farmers in rural areas to conduct agricultural work because of the affordability of farm life [17].

### Land Use Trend Analysis and Findings

Based on the basic policy of a socialist republic, all the land belongs to the country, and originally, the Vietnamese government had a policy of “Equal distribution of the land” and lent small farmlands to each household, up to 3 ha. On the other hand, Vietnam has a policy to export agricultural products as a prioritized trading item contributing to the Vietnamese national economy. The large farm registration system “Trang Trai” is one solution to strengthen Vietnamese agriculture.

Then, there are a certain portion of people who prefer doing agriculture in farming villages instead of going to cities for work because of the future expectations for doing agriculture as well as better living environment in a farming villages [14,16,19].

### 3.2. Trends in Mechanization

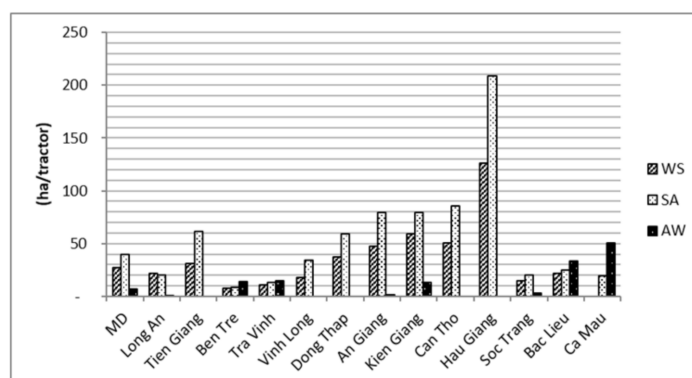
The rice production process can be classified into four main categories: (1) land preparation by tractors, (2) sowing of rice seed (direct seeding or transplanting), (3) fertilizer application and chemical spraying, and (4) rice harvesting and threshing by combine harvesters.

Due to the lack of labor power, the demand for more productive processes has become undeniable. The increased demand for mechanization has also expanded the business of farm machinery services providers among farmer households [16].

Our survey of the four categories of rice production mentioned earlier produced the following results:

#### 3.2.1. Land Preparation: By Tractors

Figure 7 shows one tractor’s covered area (hectare) for rice cultivation in each Mekong Delta province and crop season. This figure was created from our collected data from the Department of Agriculture and Rural Development (DARD) in each province, based on 58,859 units of tractors. Table 4 provides data related to whether a farmer carries out land preparation using their own tractor or a tractor provided by a farm machinery service provider. It is notable that most of the land preparation work is completed within the farmer’s own district. The amount of area covered by a tractor in each province varies greatly. Indeed, tractors are heavily used in the Hau Giang, Kien Giang, Dong Thap, and An Giang provinces, as these areas feature acid sulfate soils which require larger tractors (Figure 8).

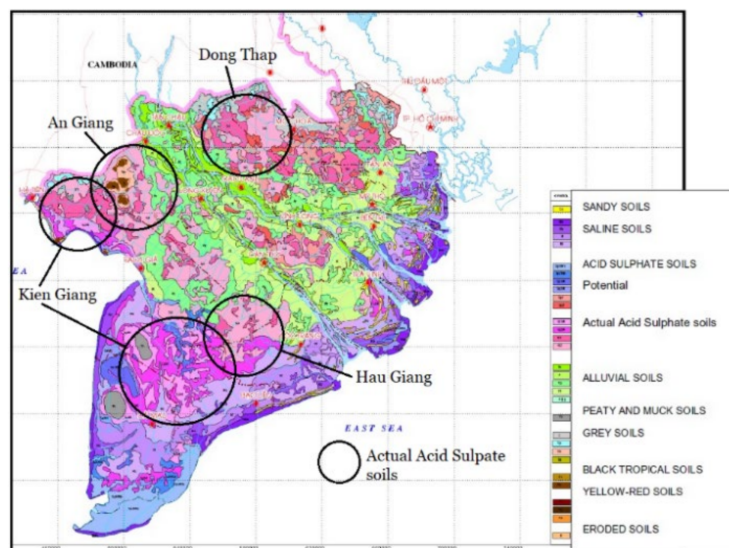


**Figure 7.** Average rice cultivation land per tractor by crop season and province in Mekong Delta; WS: Winter–Spring; SA: Summer–Autumn; AW: Autumn–Winter; MD is the average of all 12 provinces and one city in the Mekong Delta. Source: Result of interviews to DARD (Department of Agriculture and Rural Development) of all the provinces and the city in the Mekong Delta conducted by MDI-CTU members and the author in 2014.

**Table 4.** Origin of tractor service providers for rice cropping land preparation (%).

Cropping Pattern	Owners Themselves	Within Commune	Within District	Within Province	Other Provinces	Total (%)	Chitest	Chinv
1 crop (n = 73)	13.7	86.3	0.0	0.0	0.0	100.0	(p1)= 0.000	$\chi^2 = 0.000$
2 crop (n = 130)	12.1	71.4	5.0	5.0	6.5	100.0	(p2) = 0.000	$\chi^2 = 0.000$
3 crop (n = 175)	13.1	78.9	7.4	0.0	0.6	100.0	(p3) = 0.000	$\chi^2 = 0.000$
All areas (n = 378)	12.9	77.6	5.2	1.8	2.5	100.0	(p4) = 0.000	$\chi^2 = 0.000$
expected value	20.0	20.0	20.0	20.0	20.0	100.0		

Chi-square test; all patterns,  $\chi^2 = 0, p < 0.05$ . We conducted a Chi-square test and the results revealed significant differences among written conditions. n: 378 is the number of households who can use tractors in their paddy field. Source: Authors' survey.



**Figure 8.** Soil map of Mekong Delta, Vietnam. Source: Southern Institute for Water Resources Planning (SIWRP) [22].

Agricultural tractors are basic machinery used for land preparation for most agricultural products, and tractors have become the dominant piece of machinery for this purpose.

### 3.2.2. Rice Seed Sowing: Direct Seeding or Transplanting

The climate of the Mekong Delta is very suitable for rice cultivation and farmers can grow a substantial amount of rice using the manual direct seeding method known as “broadcasting”. This is the widely used seeding method of rice production in the Mekong Delta. The broadcasting method is simple and saves labor time; even farmers understand the broadcasting method requires a larger amount of seeds, fertilizers, and pesticides compared with the transplanting method [27]. In recent years, a slightly more advanced technique known as row sowing, which uses a drum seeder, became a popular device after broadcasting (Figure 9). In general, the sowing of rice seeds has not been mechanized in the majority of areas in the Mekong Delta.



**Figure 9.** Drum seeder for rice seed sowing. Source: Photo was taken by the author at An Giang province on 5 September 2014.

Methods for rice sowing differ by cultivation area and rice variety, as shown in Tables 5–7. Manual transplanting is the dominant method used in southern coastal Soc Trang province, as farmers in this region plant a special rice variety that has a long growth duration, which is nearly 160 days and does not grow well when using the manual direct seeding (broadcasting) or row sowing method.

**Table 5.** Share of rice sowing method in the Autumn–Winter season by province (%).

Sowing Method		Broadcasting	Row Sowing	Manual Transplanting	Total (%)	Chitest		Chinv	
Cropping Pattern & Provinces									
1 crop	ST (n = 35)	97.1	0.0	2.9	100.0	(p1)=	0.000	x <sup>2</sup> =	0.000
	CM (n = 70)	4.3	0.0	95.7	100.0	(p2)=	0.000	x <sup>2</sup> =	0.000
	Total (n = 105)	35.2	0.0	64.8	100.0	(p3) =	0.000	x <sup>2</sup> =	0.000
3 crops	AG (n = 35)	88.6	11.4	0.0	100.0	(p4) =	0.000	x <sup>2</sup> =	0.000
	DT (n = 35)	17.1	82.9	0.0	100.0	(p5) =	0.000	x <sup>2</sup> =	0.000
	HG (n = 35)	57.1	42.9	0.0	100.0	(p6) =	0.000	x <sup>2</sup> =	0.000
	TG (n = 67)	53.7	46.3	0.0	100.0	(p7) =	0.000	x <sup>2</sup> =	0.000
	Total (n = 172)	54.1	45.9	0.0	100.0	(p8) =	0.000	x <sup>2</sup> =	0.000
expected value		33.3	33.3	33.3	100.0				

Chi-square test; all patterns,  $\chi^2 = 0$ ,  $p < 0.05$ . We conducted a Chi-square test and results revealed significant differences among written conditions. Broadcasting: manual direct seeding. ST: Soc Trang; CM: Ca Mau; AG: An Giang; DT: Dong Thap; HG: Hau Giang; TG: Tien Giang. Source: Authors' survey.

**Table 6.** Share of rice sowing method in Winter–Spring season by province (%).

Sowing Method		Broadcasting	Row Sowing	Manual Transplanting	Total (%)	Chitest		Chinv	
Cropping Pattern & Provinces									
2 crops	AG (n = 35)	65.7	31.4	2.9	100.0	(p1)=	0.000	x <sup>2</sup> =	0.000
	DT (n = 35)	97.1	0.0	2.9	100.0	(p2) =	0.000	x <sup>2</sup> =	0.000
	HG (n = 35)	85.7	14.3	0.0	100.0	(p3) =	0.000	x <sup>2</sup> =	0.000
	ST (n = 35)	8.6	0.0	91.4	100.0	(p4) =	0.000	x <sup>2</sup> =	0.000
	Total (n = 140)	64.3	11.4	24.3	100.0	(p5) =	0.000	x <sup>2</sup> =	0.000
3 crops	AG (n = 35)	80.0	20.0	0.0	100.0	(p6) =	0.000	x <sup>2</sup> =	0.000
	DT (n = 35)	14.3	85.7	0.0	100.0	(p7) =	0.000	x <sup>2</sup> =	0.000
	HG (n = 35)	34.3	65.7	0.0	100.0	(p8) =	0.000	x <sup>2</sup> =	0.000
	TG (n = 70)	54.3	45.7	0.0	100.0	(p9) =	0.000	x <sup>2</sup> =	0.000
	Total (n = 175)	47.4	52.6	0.0	100.0	(p10) =	0.000	x <sup>2</sup> =	0.000
expected value		33.3	33.3	33.3	100.0				

Chi-square test; all patterns,  $\chi^2 = 0$ ,  $p < 0.05$ . We conducted a Chi-square test and results revealed significant differences among written conditions. AG: An Giang; DT: Dong Thap; HG: Hau Giang; ST: Soc Trang; TG: Tien Giang. Source: Authors' survey.

**Table 7.** Share of rice sowing method in Summer–Autumn season by province (%).

Sowing Method		Broadcasting	Row Sowing	Manual Transplanting	Total (%)	Chitest	Chinv
2 crops	AG (n = 35)	80.0	20.0	0	100.0	(p1)= 0.000	x <sup>2</sup> = 0.000
	DT (n = 35)	97.1	0.0	2.9	100.0	(p2) = 0.000	x <sup>2</sup> = 0.000
	HG (n = 35)	88.6	11.4	0.0	100.0	(p3) = 0.000	x <sup>2</sup> = 0.000
	ST (n = 35)	100.0	0.0	0.0	100.0	(p4) = 0.000	x <sup>2</sup> = 0.000
	Total (n = 140)	91.4	7.9	0.7	100.0	(p5) = 0.000	x <sup>2</sup> = 0.000
3 crops	AG (n = 35)	85.7	14.3	0.0	100.0	(p6) = 0.000	x <sup>2</sup> = 0.000
	DT (n = 35)	17.1	82.9	0.0	100.0	(p7) = 0.000	x <sup>2</sup> = 0.000
	HG (n = 35)	54.3	45.7	0.0	100.0	(p8) = 0.000	x <sup>2</sup> = 0.000
	TG (n = 68)	54.4	45.6	0.0	100.0	(p9) = 0.000	x <sup>2</sup> = 0.000
	Total (n = 173)	53.2	46.8	0.0	100.0	(p10) = 0.000	x <sup>2</sup> = 0.000
exopected value		33.3	33.3	33.3	100.0		

Chi-square test; all patterns,  $\chi^2 = 0$ ,  $p < 0.05$ . We conducted a Chi-square test and results revealed significant differences among written conditions. AG: An Giang; DT: Dong Thap; HG: Hau Giang; ST: Soc Trang; TG: Tien Giang. Source: Authors’ survey.

However, 26.9% of respondents expressed a desire to shift from row sowing of rice seeds to machine transplanting (Table 8), because they want to grow better quality rice or lessen the amount of work performed in the paddy field (Table 9). Four percent of respondents expressed a desire to purchase a transplanting machine (Table 10).

According to the opinion and experiences of rice farmers, rice seed producers and high-quality rice producers tend to use machine transplanting, as this rice transplanting method guarantees more mature rice, lower contamination with different rice varieties, and requires less chemicals and fertilizers compared with the broadcasting method (Table 9). Recently, a certain percentage of farmers want to shift from broadcasting or row sowing to machine transplanting, which was 3.4% to 4.8% depending on cropping patterns (Table 10).

**Table 8.** Respondents who wanted to shift from row sowing to transplanting machine (%).

Cropping Pattern	Yes	No	Total (%)
1 crop (n: 49)	22.4	77.6	100.0
2 crops (n: 42)	19.0	81.0	100.0
3 crops (n: 106)	32.1	67.9	100.0
All areas (n: 197)	26.9	73.1	100.0

Authors’ survey.

**Table 9.** Reason for shifting from row sowing to transplanting machine (%).

Reason	Cropping Pattern	1 Crop (n = 25)	2 Crops (n = 20)	3 Crops (n = 91)	All Areas (n = 136)	Expected Value
Using small amount of seed		20.0	30.0	29.7	27.9	16.7
Avoiding damage by golden snail		0.0	10.0	3.3	3.7	16.7
Easy take caring		28.0	25.0	28.5	28.0	16.7
Achieving better rice grain quality		12.0	15.0	16.5	15.4	16.7
Shortening standing time in field		28.0	10.0	4.4	9.6	16.7
Others		12.0	10.0	17.6	15.4	16.7
Total (%)		100.0	100.0	100.0	100.0	100.0
Chitest	(p) =	0.000	0.000	0.000	0.000	
Chinv	x <sup>2</sup> =	0.014	0.135	0.008	0.049	

Chi-square test; all patterns,  $\chi^2 =$  from 0.008 to 0.135,  $p < 0.05$ . We conducted a Chi-square test and results revealed significant differences among written conditions. Source: Authors’ survey.

**Table 10.** Rate of respondents who wanted to purchase transplanting machine (%).

Machine Preferred \ Cropping Pattern		1 Crop (n = 105)	2 Crops (n = 140)	3 Crops (n = 175)	All Areas (n = 420)	Expected Value
No purchase		94.2	87.9	90.9	90.7	25.0
Row sowing machine		1.0	7.1	5.7	5.0	25.0
Transplanting machine		4.8	4.3	3.4	4.0	25.0
Both row sowing + transplanting machine		0.0	0.7	0.0	0.3	25.0
Total (%)		100.0	100.0	100.0	100.0	100.0
Chitest	(p) =	0.000	0.000	0.000	0.000	
Chinv	x <sup>2</sup> =	0.000	0.000	0.000	0.000	

Chi-square test; all patterns,  $\chi^2 = 0, p < 0.05$ . We conducted a Chi-square test and results revealed significant differences among written conditions. Source: Authors' survey.

### 3.2.3. Fertilizer and Chemical Spraying

Rice farmers usually apply about 300 to 500 kg of fertilizers (N P K total) per hectare in one season, because the cultivation of 2 crops to 3 crops per year as well as the manual direct seeding method "broadcasting" require a continuous fertilizer supply to maintain soil fertility. However, only 4% of farmers use semi-mechanized fertilizer application devices (Table 11), and 85.1% of respondents wanted to transition from manual fertilizer application to a semi-mechanizing application (Table 12). Semi-mechanized fertilizer application utilizes a backpack-mounted, engine-driven fertilizer applicator. For chemical spraying, about 34.8% of rice farmers use the manual spraying method, while nearly 60% of rice farmers use the semi-mechanized method for spraying chemicals (Table 13). The semi-mechanized method refers to the use of a backpack-mounted, engine-driven chemical sprayer (Figure 10).

**Table 11.** Current status of fertilizer application method (%).

Application Method \ Cropping Pattern		1 Crop (n = 105)	2 Crops (n = 140)	3 Crops (n = 175)	All Areas (n = 420)	Expected Value
Manual fertilizing		99.0	99.3	91.4	96.0	50.0
Semi-mechanizing		1.0	0.7	8.6	4.0	50.0
Total (%)		100.0	100.0	100.0	100.0	100.0
Chitest	(p) =	0.000	0.000	0.000	0.000	
Chinv	x <sup>2</sup> =	0.000	0.000	0.000	0.000	

Chi-square test; all patterns,  $\chi^2 = 0, p < 0.05$ . We conducted a Chi-square test and results revealed significant differences among written conditions. Source: Authors' survey.

**Table 12.** Rate of respondents who wanted to use semi-mechanized fertilizer applicator (%).

Application Method \ Cropping Pattern		1 Crop (n = 104)	2 Crops (n = 139)	3 Crops (n = 160)	All Areas (n = 403)	Expected Value
Manual fertilizing		10.6	15.8	16.9	14.9	50.0
Semi-mechanizing		89.4	84.2	83.1	85.1	50.0
Total (%)		100.0	100.0	100.0	100.0	100.0
Chitest	(p) =	0.000	0.000	0.000	0.000	
Chinv	x <sup>2</sup> =	0.000	0.000	0.000	0.000	

Chi-square test; all patterns,  $\chi^2 = 0, p < 0.05$ . We conducted a Chi-square test and results revealed significant differences among written conditions. Source: Authors' survey.

**Table 13.** Current status of chemical spraying method (%).

Status	Cropping Pattern	1 Crop (n = 105)	2 Crops (n = 140)	3 Crops (n = 175)	All Areas (n = 420)	Expected Value
No chemical application		5.7	0.0	0	1.4	25.0
Manual spraying		77.2	20.7	20.6	34.8	25.0
Semi-mechanized spraying		13.3	72.9	77.1	59.8	25.0
Mechanized spraying		3.8	6.4	2.3	4.0	25.0
Total (%)		100.0	100.0	100.0	100.0	100.0
Chitest	(p)=	0.000	0.000	0.000	0.000	
Chinv	x <sup>2</sup> =	0.000	0.000	0.000	0.000	

Chi-square test; all patterns,  $\chi^2 = 0, p < 0.05$ . We conducted a Chi-square test and results revealed significant differences among written conditions. Source: Authors' survey.



**Figure 10.** Agrochemical sprayers, (A): Semi-mechanized chemical sprayer sold in Vietnam; (B): Local made riding type sprayer; (C): Riding type sprayer imported and sold in Vietnam. Source: Photos A and B were taken by the author at An Giang province on 5th September 2014; photo C is from a catalogue of a Japanese manufacturer [28].

### 3.2.4. Rice Harvesting: By Combine Harvester

Rice harvesting methods in the Mekong Delta changed dramatically, switching from manual harvesting or reaper harvesting methods to the use of combine harvesters. Rice is harvested by combine harvester in the majority of regions which use double or triple rice cropping methods. However, such as in Soc Trang or Ca Mau, manual harvesting is the predominant method. This is because the soil is muddy and soft, so combine harvesters cannot work properly (Table 14). In all areas, the majority of combine harvesters were used for harvesting within a single commune of farmers (Table 15).

**Table 14.** Current status of harvesting by cropping pattern and season (%).

Season and Method	Cropping Pattern	1 Crop (n = 105)	2 Crops (n = 140)	3 Crops (n = 175)	All Areas (n = 420)	Expected Value
Autumn– Winter	Manual harvesting	88.6		0.0	35.1	50.0
	Combine harvester	11.4		100.0	64.9	50.0
	Total (%)	100.0		100.0	100.0	
Winter– Spring	Manual harvesting		1.4	0.0	0.6	50.0
	Combine harvester		98.6	100.0	99.4	50.0
	Total (%)		100.0	100.0	100.0	
Summer– Autumn	Manual harvesting		2.1	0.0	1.0	50.0
	Combine harvester		97.9	100.0	99.0	50.0
	Total (%)		100.0	100.0	100.0	
Chitest	(p)=	0.000	0.000	0.000	0.003	
Chinv	x <sup>2</sup> =	0.000	0.000	0.000	0.000	

Chi-square test; all patterns,  $\chi^2 = 0, p < 0.05$ . We conducted a Chi-square test and results revealed significant differences among written conditions. Source: Authors' survey.



**Table 15.** Origin of farm machinery service supplier for harvesting, by rice cropping pattern (%).

Cropping Pattern	Harvesting Service	Owner Themselves	Within Commune	Within District	Within Province	Other Provinces	Total (%)	Chitest	Chinv
1 crop (n = 105)		6.7	87.5	3.8	1.0	1.0	100.0	(p1)= 0.000	x <sup>2</sup> = 0.000
2 crops (n = 140)		5.0	60.0	7.1	2.9	25.0	100.0	(p2)= 0.000	x <sup>2</sup> = 0.000
3 crops (n = 175)		2.3	68.6	4.0	2.9	22.2	100.0	(p3)= 0.000	x <sup>2</sup> = 0.000
All areas (n = 420)		4.3	70.5	5.0	2.4	17.8	100.0	(p4)= 0.000	x <sup>2</sup> = 0.000
expected value		20.0	20.0	20.0	20.0	20.0	100.0		

Chi-square test; all patterns,  $\chi^2 = 0$ ,  $p < 0.05$ . We conducted a Chi-square test and results revealed significant differences among written conditions. Source: Authors' survey.

### 3.3. Mechanization Trend Analysis and Findings

Major working processes for rice cultivation include land preparation, rice seed sowing or transplanting, fertilizing and chemical spraying, and harvesting; most of those processes have been mechanized until today, except for rice seed sowing or transplanting processes. We understand the most influential reason for mechanization is working load, cost of work, and investment effects. However, a new mechanization movement is also taking place by an introduction of new technology from agricultural machinery manufacturers. The government's trade policy for tariff incentives also works to accelerate a new technology import from overseas.

#### 3.3.1. Land Preparation

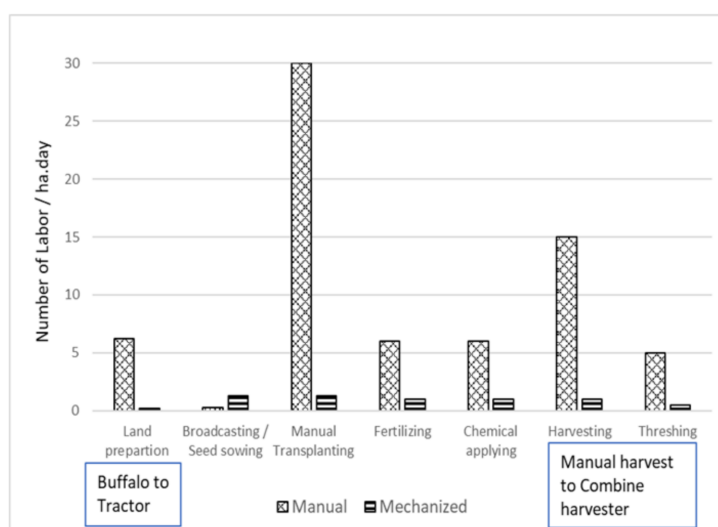
Historically, water buffaloes were used for land preparation in Vietnam. However, currently, power tillers or tractors cover land preparation work almost 100% in the Mekong Delta. The majority of agricultural tractors are secondhand tractors imported from Japan. According to Japanese Customs data, from 2011 to 2018, more than 20,000 units of agricultural tractors were exported from Japan to Vietnam every year, and most of those were secondhand tractors [20]. Reasons of such trends are: (1) the output horsepower range of Japanese tractors is about 30 to 50 hp and light weight, which fits the demand of rice production use in Vietnam; (2) another reason is the low import tax rate to Vietnam, which is 0% (maximum 5%) at this moment based on the Japan–Vietnam EPA (Economic Partnership Agreement). To avoid misunderstanding of tractor import numbers to Vietnam, 30 to 40% of imported secondhand tractors were re-exported to other countries after being reconditioned in Vietnam. Many tractor reconditioning companies and workshops are available, mostly in Long An province and western part of Ho Chi Minh City (Figure 11).



**Figure 11.** A tractor reconditioning company in Long An province. Source: Photo was taken by the author at Long An province in September 2009. These kinds of companies are still available in 2020.

An agricultural tractor has a big advantage in land preparation against plowing by a water buffalo in its higher productivity and less labor-intensive work (Figure 12). We predict the sales of brand-new tractors will be increased within the next several years, along with the improvement of

agricultural profitability coming from better quality and productivity of rice, which happened in Thailand after 2003.



**Figure 12.** Required number of labor for one ha, done in one day for each process of rice cultivation. This figure is a brief image of farmers with whom we interviewed, and we picked up data from other reports from the FAO and IRRI (International Rice Research Institute); however, these numbers are not measured scientifically. Source: Authors' survey, also FAO [29] and IRRI [30] information.

### 3.3.2. Sowing Process

As shown in Figure 13, from our interviews with farmers about rice production expenses, it seems farmers consider the rice seed sowing process as their family work and outside of the main rice production expenses. Farmers accept doing manual direct seeding (broadcasting), because broadcasting work does not require hard work (Figure 12) and they can obtain a certain good yield of rice. In our direct interviews with farmers, 57.8% of farmers perform manual direct seeding (broadcasting) (Figure 14). However, farmers know the quality and selling price of transplanted rice is much higher than broadcasted rice, which influences their income. Yet, the majority of farmers hesitate to use a rice transplanting machine because of its investment cost, and the transplanting method also requires a rice seedling nursery process before transplanting.

We need to prepare and propose a suitable mechanization idea of sowing process to Mekong Delta farmers in order to achieve profitable rice production with a less labor-consuming sowing process.

### 3.3.3. Fertilizing and Agrochemical Spraying

As reported in Section 3.2.3, semi mechanized machines for fertilizing and chemical spraying are becoming popular among Mekong Delta farmers. However, a riding-type full mechanized fertilizing machine is rarely available. One is a fertilizer application device driven by a tractor, another type is a fertilizer applicator mounted on a transplanting machine, which is partly introduced to the market. Full mechanized chemical spraying machines are imported (Figure 10C) but sold in very small numbers due to their high pricing. A local technician makes a riding-type chemical sprayer (Figure 10B) for their own use, but this is also rare in the market.

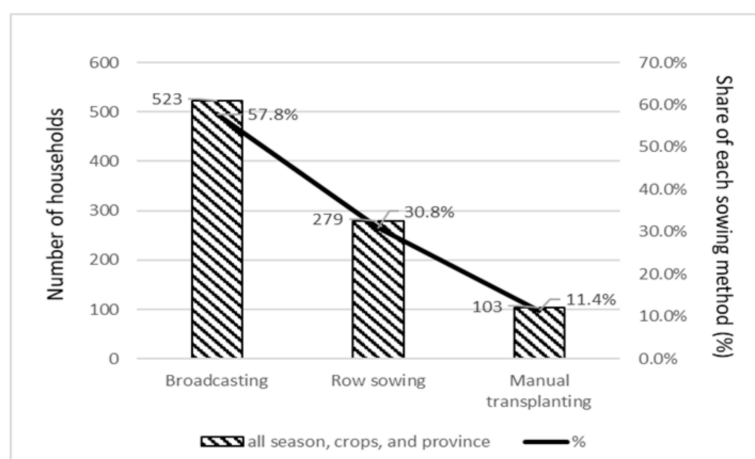
On the other hand, according to our interviews with farmers, among agricultural expenses in rice production, fertilizer costs and pesticide costs occupy more than 50% of all the expenses (Figure 13). Then, the reduction of fertilizer and pesticide consumption is a very important issue. One solution is transplanting instead of broadcasting in the sowing process, which can also reduce the volume of weeding pesticides. Another possibility is a fertilizer applicator mounted on a transplanter, which has a function of side strip fertilization to save the volume of fertilizer consumption (Figure 15).

### 3.3.4. Harvesting

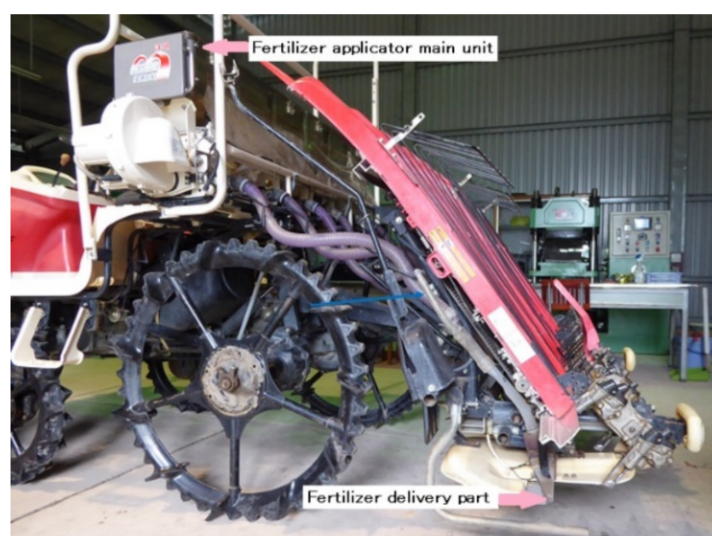
The rice harvesting process dramatically changed in 2006; before that, most of harvesting work was performed by manual work, and rice reaping machines were not accepted generally. At first, Chinese brand combine harvesters were introduced to the Mekong Delta. Then, farmers recognized its high productivity for harvesting and a rice threshing function was also welcomed (Figure 12). After Chinese combine harvesters were introduced, Japanese brand combine harvesters achieved a major share of combine harvester sales in the Mekong Delta. Currently, more than 20,000 units of combine harvesters were introduced to the Mekong Delta, and rice is harvested by combine harvesters in most of areas [20].



**Figure 13.** Share of rice cultivation expenditures. Results of interview with farmers. We conducted a Chi-square test and the results revealed significant differences among written conditions. The harvesting cost of the Autumn–Winter season is bigger than other seasons because it includes a manual harvesting area. Source: Authors’ survey.



**Figure 14.** Share of each sowing method; accumulated data from Tables 5–7; all season, cropping pattern, and province data were accumulated. Source: Authors’ survey.



**Figure 15.** Fertilizer applicator mounted on a rice transplanter. Side strip fertilization device is equipped, fertilizer to be delivered to the beneath of the soil. Source: Photo was taken by the author at Can Tho city in December 2019.

#### 3.4. Policy Initiatives Supporting Mechanization

In addition to the large farm registration system, the Vietnamese government has also provided financial support as per the Prime Minister's Decision No.68/2013/QĐ-TTg dated 14 November 2013, according to which the government supports 100% of interest for two years, and an additional 50% of interest for the third year on loans for farmers to purchase agricultural machineries through appointed banks. Farmers can also apply this decision scheme for purchasing foreign brand machineries. This decision has accelerated the purchasing of agricultural machineries and upgrading of mechanization of farming by the Mekong Delta farmers in recent years.

The Vietnamese government provides a low import tax rate for farm machineries to support farmers for mechanization. As we mentioned in Section 3.3.1, the Japan–Vietnam EPA was agreed in 2008 and enforced in 2009, and among ASEAN countries, ATIGA (ASEAN Trade in Goods agreement) was also agreed and enforced in 2015. Finally, import tax of most farm machineries became 0%.

#### 3.5. Environmental Movements

There are several environmental issues related to rice production in the Mekong Delta. However, “sustainable agriculture” or “agriculture with low environmental load” seems to be not a popular subject among the Mekong Delta farmers.

One is rice straw treatment after harvest. It is decreasing but a certain share of farmers still burn rice straw on the paddy field after harvest. Some local governments have taken actions to ban the burning of rice straw after rice harvesting in order to reduce greenhouse gas (GHG) emissions from paddy fields; for example, the Hanoi city government issued decree No.6454/UBND-DT on 9 November 2016, and the Thai Binh provincial government issued decree No.2265/UBND-NNTNMT on 7 June 2019. However, a national-level decree or decision to ban the rice straw burning has not been issued.

Another one is excessive use of fertilizer and agrochemicals, which pollute waterways and other nature. According to a World Bank report issued in 2017, 140,000 tons of N, 82,000 tons of P, and 66,000 tons of K are wasted in the Mekong Delta annually, which has a value of USD 150 million and increases the burden of farmers [31–33]. Nutrient management is an important activity for balancing suitable fertilizer supply for rice production [34].

The influence of climate change is also an inevitable environmental issue. In recent years, because of some changes of the Mekong river stream, coastal provinces in the Mekong Delta, such as the Soc Trang and Ben Tre provinces, saltwater intrusion seriously harms rice cultivation. The Vietnamese

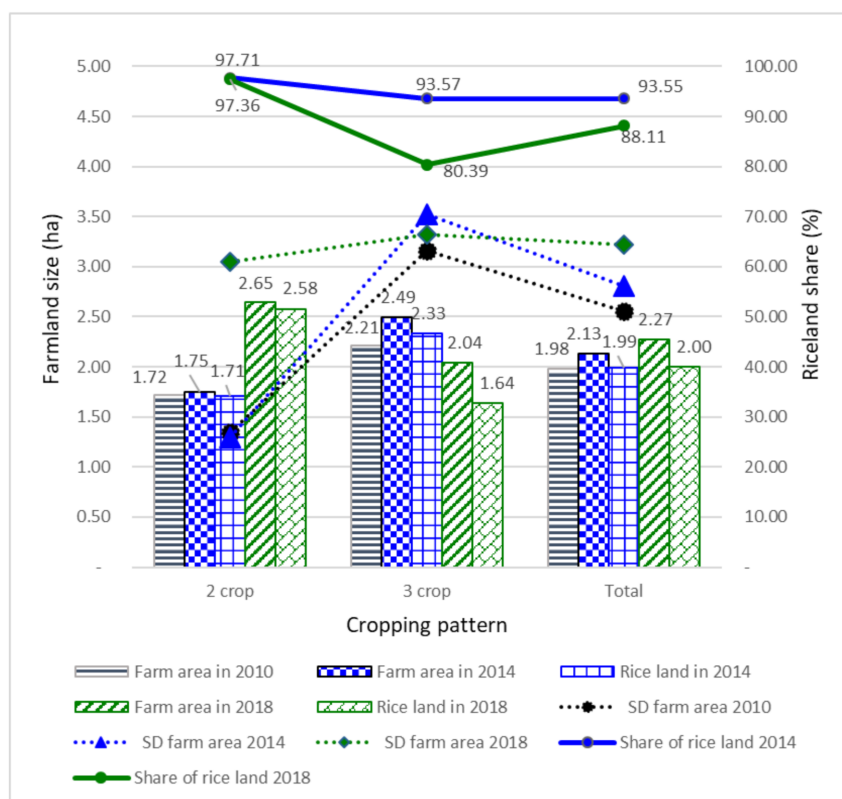
government and some overseas aid worked towards water management and the development of salt-tolerant rice varieties has also been progressed by researchers [2,23,35–37].

### 3.6. Rice production Movements after the Survey in 2013 and 2014

After we surveyed the Mekong Delta’s rice production in 2013 and 2014, we carried out follow up data collection and analysis to find out changes related to the rice production industry in the Mekong Delta up to 2019, and confirmed the following facts and trends:

#### 3.6.1. Farmland Size Change in the Mekong Delta; Farmland/Household Increased

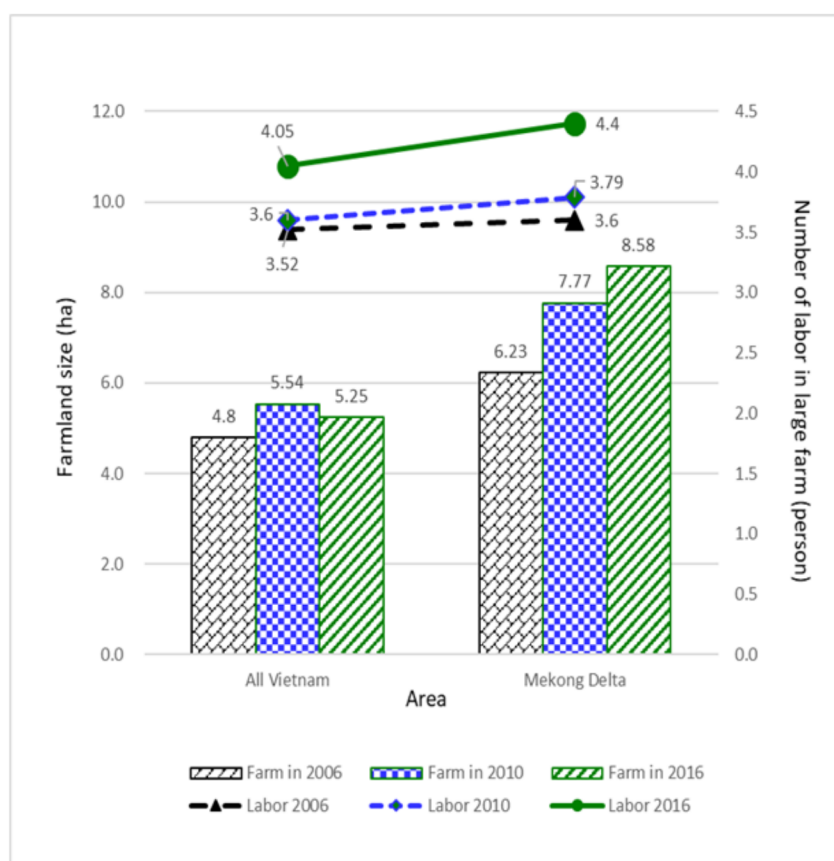
According to the survey data (420 farms) of the authors in 2014 and survey data (600 farms) of the Mekong Delta Development Research Institute of Can Tho University (MDI-CTU) in 2018, farmland size per farmer household in the Mekong Delta increased from 2.13 ha in 2014 to 2.27 ha in 2018; among them, farmland in two crop areas increased remarkably from 1.75 ha in 2014 to 2.65 ha in 2018. However, rice paddy land share in all the farmland decreased from 93.55% in 2014 to 88.11% in 2018; especially, rice land share in three crop areas dropped from 93.57% in 2014 to 80.39% in 2018 [10,13] (Figure 16). We understand this is partly influenced by the government’s instruction for farmers to change their production items from rice to other profitable crops.



**Figure 16.** Change of farmland size/household from 2010 to 2014, and 2018 in the Mekong Delta. Two-crop, three-crop, all areas’ average, and share of rice land in all farmland. Source: created from survey data in 2014 and 2018 by the Mekong Delta Development Research Institute of Can Tho University (MDI-CTU).

#### 3.6.2. Trend of Registered Large Farm “Trang Trai”

Figure 17 shows the average size of “Trang Trai” farms in the Mekong Delta increased continuously from 6.23 ha/farm in 2006 to 7.77 ha/farm in 2010, and 8.58 ha/farm in 2016. However, the average “Tran Trai” farm size in all of Vietnam has not increased.



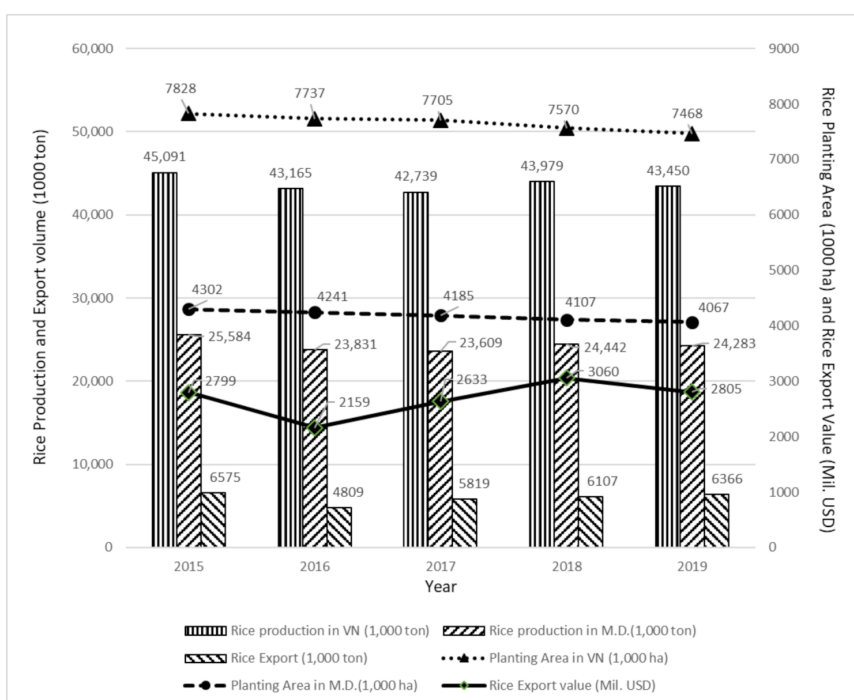
**Figure 17.** Change of registered large farms from 2006 to 2016. Farmland size/farm and amount of labor/farm in all Vietnam and in the Mekong Delta. Source: created from GSO 2013, 2016 [9,11].

### 3.6.3. Trend of Rice Production and Paddy Area

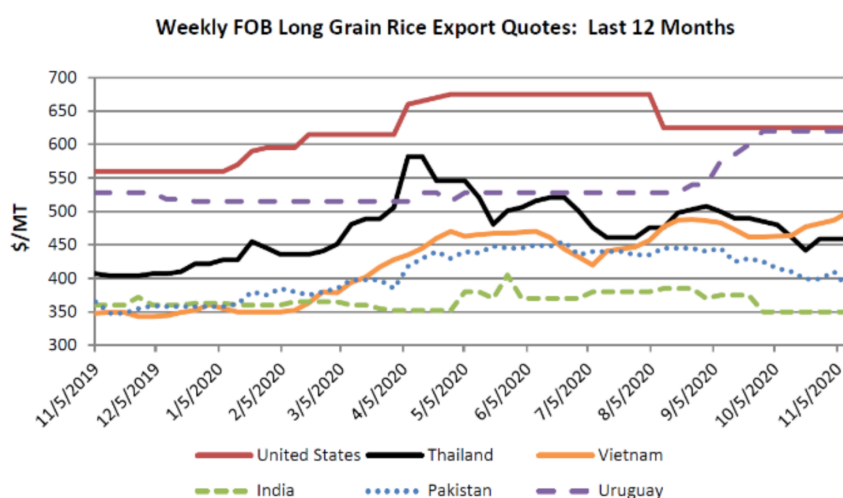
Nevertheless, even though the Vietnamese government recommended farmers to shift rice production to other profitable crops, total paddy area in all Vietnam and Mekong Delta decreased very little from 2015 to 2019. Rice production volume also keeps almost same numbers (Figure 18) [10–13].

Vietnamese rice has been generally considered as “low quality rice” [4]; however, many researchers or institutes in the Mekong Delta have been trying to develop higher quality rice varieties. A research group in Soc Trang province developed a new variety “ST25”, and finally, in 2019, they received the No.1 award of “World’s Best Rice Contest 2019” held in Manila, the Philippines [38]. It is a short one-year trend, but Vietnamese rice trading price on the international market increased rapidly and achieved a higher price than Thai rice in November 2020 (Figure 19).

Another movement is the growth of huge rice producers. One example is Loc Troi Group, which cultivates rice in the area of more than 40,000 ha annually with contract farming; they also develop several new rice varieties by themselves.



**Figure 18.** Transition of rice planting area, rice production volume, and rice export volume and value from 2015 to 2019. Rice production in Vietnam and the Mekong Delta is paddy rice volume, and rice export is milled rice volume.; Source: created from GSO and Vietnam Customs data [39,40].



**Figure 19.** Rice Trading Prices of major rice exporting countries from November 2019 to November 2020. Source USDA: Grain: World Markets and Trade November 2020 [41].

#### 4. Conclusions

Agriculture is one of the leading industries of Vietnam. Vietnam is also a top rice supplier to neighboring countries, such as the Philippines, Indonesia, and southern provinces of China. Sustainable agricultural development is the key issue of Vietnam. In this study, we focused on the rice production transition in the Mekong Delta.

Considering the agricultural environment, the average size of farmland per household in the Mekong Delta has increased from 1.98 ha/household in 2010 to 2.27 ha/household in 2018 (Figure 16); among them, the average size of rice land/household has not increased much. However, a remarkable change was the introduction of the large farm registration system “Trang Trai” in 2000. We understand it was a special solution of the Vietnamese government, because Vietnamese land law still keeps a land

borrowing limitation of 3ha/household, but the “Trang Trai” system allowed over 3ha land to be lent as a business farm registration. As a result of several revisions to the system, a farmer can now borrow up to 30ha/household of farmland for 50 years. As a consequence of the industrialization of Vietnam, many rural inhabitants have migrated to cities, resulting in a decrease in the rural labor force and an increased need for agricultural mechanization.

For the development of the rice production industry, improvements in quality, productivity, and profitability are all very important issues. Concerning the agricultural mechanization situation, we studied the following four major processes of rice production: (1) land preparation, (2) seed sowing, (3) chemical and fertilizer application, and (4) harvesting and threshing. Among these four processes, we found that only the seed sowing process has not been thoroughly mechanized. We understand the mechanization of sowing method, such as sifting from broadcasting to machine transplanting, can produce higher quality rice and a lower consumption of fertilizers and agrochemicals. We need further study on machine transplanting with practical experiments to find out the best pattern of transplanting, which can be accepted by farmers.

Among Mekong Delta farmers, “sustainable agriculture” and “agriculture with low environmental load” appear to be unpopular concepts. However, the government has taken several steps to protect the environment, such as banning the burning of rice straw in paddy fields after harvesting, instruction to reduce fertilizer volume which is overused, or promoting the installation of biogas processing systems at pig farms. The government also works to protect paddy fields in coastal areas against saltwater intrusion caused by climate change.

In order to develop the rice production industry in the Mekong Delta, it is better to consider the overall balance of all related factors, such as productivity, profitability, quality, environmental load, and workforce balance. We learned about various movements of agriculture in the Mekong Delta regarding land use, farmers’ structure, and mechanization transition based on our gathered information. One good trend of recent rice production is the quality upgrade of Vietnamese rice. Within one year, from October 2019 to November 2020, the trading price of Vietnamese rice increased rapidly and reached a higher price than Thai rice. Especially, winning of the rice variety “ST25” at the world’s best rice contest 2019 symbolizes high quality of Vietnamese rice [38].

Sooner or later, we expect the rice seed sowing or transplanting method will be mostly mechanized. Then, most of the cultivation process will be mechanized, or even IT technologies will make farming life more convenient. We expect those changes will also help to retain farmers within farming villages.

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